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CERTIFICATE

This certificate is issued in support of an application for Patent registration in a country outside New Zealand pursuant to the Patents Act 1953 and the Regulations thereunder.

I hereby certify that annexed is a true copy of the Provisional Specification as filed on 30 September 2002 with an application for Letters Patent number 521717 made by KENNETH WILLIAM PATTERSON DRYSDALE.

Dated 16 September 2003.

Neville Harris

Neville Harris
Commissioner of Patents, Trade Marks and Designs

COMMISSIONER OF PATENTS, TRADEMARKS & DESIGNS
NEW ZEALAND

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521717

Patents Form No. 4 Our Ref: CC504100

Patents Act 1953

PROVISIONAL SPECIFICATION

AIR CONDITIONING APPARATUS AND METHOD

I, **KENNETH WILLIAM PATTERSON DRYSDALE,** a citizen of Australia, of 8A Elm Avenue, Belrose, New South Wales, Australia do hereby declare this invention to be described in the following statement:

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30 SEP 2002
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Air Conditioning Apparatus And Method

Technical Field

The present invention relates to thermodynamic cycles and apparatus for air conditioning and/or refrigeration and more particularly, but not exclusively, to a new air conditioning apparatus and a method of air conditioning.

Background

Air conditioning systems have become a huge draw on electricity power in many of the major cities of the world and are viewed as an essential component of many large buildings in order to maintain a level of environmental control within the building. At the same time as air conditioning systems continue to increase in number, it is becoming increasingly recognised that electricity is a limited resource and in some places demand is exceeding supply or is forecast to in the near future.

It has become important to identify potential areas for saving in electricity consumption. If any savings can be made in air conditioning systems, then there is potential to make an overall huge saving in the consumption of electricity.

It is therefore an object of the present invention to provide an air conditioning apparatus or a method of air conditioning that may be used to provide at least some savings in electricity consumption or at least one that will provide the public with a useful alternative.

Further objects of the present invention may become apparent from the following description.

Summary of the Invention

According to one aspect of the present invention there is provided an air-conditioning apparatus including at least a first refrigerant cycle containing a first refrigerant and a second refrigerant cycle containing a second refrigerant, each said refrigerant cycle including in order, a compressor to compress the refrigerant, a condenser to reject heat, a receiver to collect the refrigerant, a first turbine to generate power, an evaporator to absorb heat and a second turbine to generate power, wherein at least a

portion of the heat rejected from said condenser in said first refrigerant cycle is absorbed by said evaporator of said second cycle and one or both of said first and said second refrigerant cycles includes a respective control system, the or each said control system including;

- sensing means for providing a measure of an output of the respective refrigerant cycle;
- control means for the compressor of the respective refrigerant cycle, wherein the control means is in communication with said sensing means to receive as inputs said measure of an output of the respective refrigerant cycle and a measure of the work input of the compressor;
- wherein the control means is operable to compute a measure of efficiency from said inputs and vary the speed of the compressor to maximise said measure of efficiency or to maintain said measure of efficiency at a predetermined level.

Preferably, the or each control system may include second control means for controlling said condenser of said respective refrigeration cycle, the control system varying the operation of the condenser to maintain a required level of cooling of refrigerant by the condenser.

Preferably, the or each control means and the or each second control means may be a single microcontroller or microprocessor or a plurality of microcontrollers or microprocessors.

Preferably, at least a portion of the power generated by one or both of said first turbine and second turbines of either or both of said first and second refrigerant cycles may contribute to a power input of one or both of said compressors.

Preferably, the boiling point of said second refrigerant may be greater than the boiling point of said first refrigerant.

Preferably, the condensing temperature range of said first refrigerant may be substantially equal to the evaporating temperature range of said second refrigerant.

Preferably, said first refrigerant may be R22.

Preferably, said second refrigerant may be R11.

According to a second aspect of the present invention there is provided a method of air conditioning, the method including providing at least a first refrigerant cycle containing a first refrigerant and a second refrigerant cycle containing a second refrigerant, each said refrigerant cycle including in order, a compressor to compress the refrigerant, a condenser to reject heat, a receiver to collect the refrigerant, a first turbine to generate power, an evaporator to absorb heat and a second turbine to generate power, wherein at least a portion of the heat rejected from said condenser in said first refrigerant cycle is absorbed by said evaporator of said second refrigerant cycle ,

the method further including providing one or both of said first refrigerant cycle and said second refrigerant cycle with a respective control system including;

- sensing means for providing a measure of an output of the respective refrigerant cycle;
- control means for the compressor of the respective refrigerant cycle, wherein the control means is in communication with said sensing means to receive as inputs said measure of an output of the refrigerant cycle and a measure of the work input of the compressor;
- wherein the control means is operable to compute a measure of efficiency from said inputs and vary the speed of the compressor to maximise said measure of efficiency or to maintain said measure of efficiency at a predetermined level.

Further aspects of the present invention may become apparent from the following description, given by way of example only and with reference to the accompanying drawings.

Brief Description of the Drawings

Figure 1: Shows a schematic view of an air-conditioning apparatus according to one aspect of the present invention.

Figure 2: Shows a plan view of an expansion turbine suitable for use with the present invention.

Figure 3: Shows a cross-sectional view of the expansion turbine in its housing, with part of the housing removed for clarity.

Figure 4: Shows, very diagrammatically, a view of a preferred nozzle for use with the expansion turbine.

Figure 5: Shows, very diagrammatically, a layout for a preferred evaporator for use with either of the refrigerant cycles of the air-conditioning apparatus of the present invention.

Detailed Description of the Drawings

Although the present invention is described herein with respect to its use as an air conditioning apparatus, those skilled in the art will appreciate that the same apparatus may be used as a refrigerator or as a heat pump.

Referring first to Figure 1, an air conditioning apparatus according to one aspect of the present invention includes first and second refrigerant cycles, generally referenced by arrows 100 and 200 respectively.

The first refrigerant cycle 100 includes, in order, a compressor 9A to compress the first refrigerant, a condenser 11A to reject heat from the refrigerant, a receiver 13A to collect the refrigerant, a first turbine 300A to generate power, an evaporator 6A to absorb heat and a second turbine 10A to generate power. The cycle may also optionally include one or more of a thermoelectric generator 12A and accumulator (not shown).

The second refrigerant cycle 200 also includes a compressor 9B to compress the second refrigerant, condenser 11B, receiver 13B, first turbine 300B, evaporator 6B and second turbine 10B in the same order as they are arranged in the first cycle 100.

Some, or more preferably all, of the heat rejected by the condenser 11A of the first cycle 100 may be absorbed by the evaporator 6B of the second cycle 200.

Power generated by any of the turbines 300A, 300B, 10A, 10B, may preferably be used to contribute to the power requirements of one or both of the compressors 9A, 9B, although alternatively the power, which those skilled in the art will recognise may be

electrical power, shaft power, or power in another suitable form, may be used for some other purpose.

Referring next to Figures 2 and 3, a turbine suitable for use as the first turbine 300A, 300B of either or both of the refrigerant cycles 100, 200 is hereinafter referred to as an expansion turbine and is generally referenced by arrow 400.

The expansion turbine 400 may include a central shaft 1 adapted to receive a liquid, typically liquid refrigerant such as, for example, R22, R11 or R134A, into a central chamber 1A via a rotating union 2 located substantially on its central axis. The refrigerant travels through the central chamber 1A of the expansion turbine 400 and is distributed to apertures, seen in Figure 3, extending through each of the curved arms 3 which extend radially from the central chamber 1.

Each arm 3 has a constantly diminishing internal cross-sectional area and terminates in a nozzle 4. As the liquid refrigerant travels down each turbine arm 3 it is accelerated due to the diminishing cross-section.

The expansion turbine 400 may be housed in a turbine housing 500.

The expansion turbine 400 may be configured for either subsonic, or more preferably supersonic operation.

Referring next to Figure 4, in the preferred supersonic embodiment the nozzle 4 may have a converging section 4A followed by a diverging section 4B. In the most preferred embodiment, most or all of the liquid refrigerant may flash to vapour near the throat 5 of the converging/diverging nozzle 4, preferably downstream of the throat 5. The centerline of the nozzle 4 may preferably be substantially straight, and the ratio of the area of nozzle entrance 4C to the throat 5 may preferably be 6:1 or greater. The half angle 4D of the walls of both the converging section 4A, and diverging section 4B, should preferably be less than 30 degrees for supersonic flow, but more preferably around 15 degrees.

Preferably the gaseous refrigerant may be traveling at a velocity of at least the local speed of sound at or near the throat 5, and the pressure of the refrigerant at the throat 5 may be sufficiently low for the refrigerant to accelerate to supersonic speeds in

the diverging section 4B. The change of phase and the expansion of the gaseous refrigerant during this acceleration may cause a drop in the temperature of the refrigerant.

Referring back to Figures 2 and 3, in the case of supersonic operation, it may be necessary to heat the turbine housing 500 in order to create the temperature and pressure conditions necessary for a sufficient amount of the refrigerant to change phase to create supersonic flow in the nozzle 4. In this case the turbine housing 500 may include a heating fluid inlet 14 and outlet 15 to carry hot fluid through the housing 500. This heating may not be necessary for subsonic operation.

Referring again to Figure 4, in the case of subsonic operation, the diverging section 4B may be omitted and a lower proportion of the refrigerant may flash to vapour.

The jet of refrigerant exiting the nozzle 4 may cause a reaction force on the arm 3, thereby providing a torque to drive the expansion turbine 400 in the opposite direction. To maximize the torque provided, the nozzle 4 may direct the jet of refrigerant substantially tangentially to the path of the nozzle 4.

The arms 3 may be curved to provide a smooth change in direction from the central chamber 1 to the nozzle 4, thereby minimizing frictional losses.

Those skilled in the art will further appreciate that the expansion turbine 400 may provide a torque regardless of whether the refrigerant exiting the nozzle 4 is supersonic or subsonic, and regardless of the phase of the fluid exiting the nozzle 4.

Those skilled in the art will also appreciate that the expansion turbine 400 effectively performs the function of the throttling or T_X valve of the prior art while recovering energy from the expansion of the refrigerant. If the combined cross-sectional areas of the nozzles 4 are sized to allow sufficient refrigerant to flow to provide the air-conditioning effect required then the T_X valve may be eliminated.

Referring next to Figures 1 and 5, in a preferred embodiment the refrigerant exiting the first turbine 300A of the first cycle 100 may be supersonic. In this case the conduit 7 inside the evaporator 6A may preferably be of a smoothly curved substantially spiral, or optionally helical shape, in order to recover the maximum energy from the high speed flow when the refrigerant enters the second turbine 10A.

The spiral shape conduit 7 may avoid the sudden changes of direction common in evaporators of the prior art, which typically force the flow to execute a series of tight 180° turns. The evaporator 6A may thereby allow the refrigerant to maintain a high speed as it absorbs heat from a heating medium, which may typically be ambient air. In this way the pressure in the evaporator 6A and the pressure drop across the evaporator 6A may be minimized, which may assist in minimizing the deterioration in air-conditioning effect which might otherwise be caused by attempting to maintain such a high speed flow in a evaporator of the prior art.

Preferably, the internal cross-sectional area of the conduit 7 may continuously increase in order to allow the supersonic refrigerant to accelerate as it travels through the evaporator.

In one embodiment the refrigerant may be traveling at a sufficient speed to allow it to be fed straight onto the second turbine 10A from the evaporator 6A without the need for a nozzle. A suitable turbine is described in the applicants co-pending New Zealand patent application No. 517088, which is hereby incorporated herein in its entirety where appropriate.

In another embodiment the gaseous refrigerant may be decelerated by a diffuser (not shown) upstream of the second turbine 10A , thereby increasing its pressure. In this case a nozzle may be needed to accelerate the refrigerant to a suitable speed for the second turbine 10A.

Those skilled in the art will appreciate that the turbine and evaporator described above may also be used with the second refrigerant cycle 200.

In some embodiments it may be desirable to house the expansion turbine 300A and the second turbine 10A in the housing of the evaporator 6A. This may not be desirable in supersonic embodiments however, as the heat load from the heated turbine housing 500 may decrease the air-conditioning performance.

The control system for the first refrigerant cycle 100 may use a micro controller which may receive as inputs the target co-efficient of performance COP_1 of the first refrigerant cycle 100, a required motor speed increment K_2 for the compressor 9A and an air conditioning

refrigerant constant K_1. K_1 may be determined experimentally for the particular air conditioning cycle 100. These inputs may be entered manually through a user interface, such as a keypad. Alternatively, these inputs may be set at the time of programming of the microcontroller.

In addition, the microcontroller may receive as inputs the temperature of the air flowing into the evaporator T_1, the temperature of the air leaving the evaporator T_2 and the compressor motor power W_1. Having received these inputs, the microcontroller may then compute the actual co-efficient of performance COP_2 of the cycle 100 according to the equation:

$$COP_2 = K_1|T_1-T_2| / W_1$$

Other measures relating the output of the cycle to the compressor work input may be used if required. As herein described, the presently contemplated preferred embodiment uses measures of temperature difference to provide a measure of the useful heat transferred by the system, as temperature measurements may be relatively easily obtained. However, alternative measures of system performance may be used that relate the system output to the compressor input.

The computed co-efficient of performance COP_2 is then compared to the target, COP_1. If the value of the target COP_1 is less than COP_2, the compressor speed is increased by an increment K_2. Conversely, if the target COP_1 is greater than the computed COP_2, the motor speed is decreased by K_2. A delay subroutine is then executed to allow for any lag in the response of the cycle to the change in compressor speed. The required time delay can be determined experimentally by forcing adjustments of the compressor speed by increments of K_2 and measuring the maximum time for the air conditioning cycle to return to steady state conditions.

Temperatures representative of the state of the refrigerant within the cycle 100 may be measured, for example any one or more of the set point in the control area of the apparatus, that is, the area which the apparatus is intended to heat or cool, the evaporator output temperature and the refrigerant temperature immediately after the evaporator 6A.

The speed of the fans (not shown) controlling the air flow over the evaporator 6A and/or condenser 11a may also be controlled by the control system in order to ensure that

the refrigerant conditions within the refrigerant cycle 100, for example refrigerant pressure, temperature, and/or vapour fraction, are all kept within suitable limits at critical points in the cycle. The heat input and/or output of the apparatus may also be varied by this means.

Those skilled in the art will appreciate that essentially the same control system may be applied to the second refrigerant cycle 200, although in some embodiments, one of said first and second refrigerant cycles may not be provided with such a control system.

Although the air conditioning apparatus has been described above as having two refrigerant cycles, those skilled in the art will appreciate that one or more further refrigerant cycles may be added, the evaporator of each additional cycle absorbing heat from the condenser of the previous refrigeration cycle. If required, the COP of each additional refrigerant cycle may be controlled by a further control system substantially as described above, or a single microprocessor may control the COP of each refrigerant cycle, or the overall COP of the combined apparatus.

The applicant believes that by operating an air-conditioning apparatus as herein described with an appropriate control system to control the coefficient of performance of at least one of the refrigerant cycles, that the power required to run the apparatus may be substantially reduced over some air-conditioning cycles of the prior art.

Where in the foregoing description reference has been made to specific components or integers having known equivalents, then such equivalents are hereby incorporated herein as if individually set forth.

The foregoing description of the invention has been given by way of example only and with reference to preferred embodiments as presently contemplated. Those skilled in the relevant arts will appreciate that modifications or improvements may be made to the invention without departing from its scope.

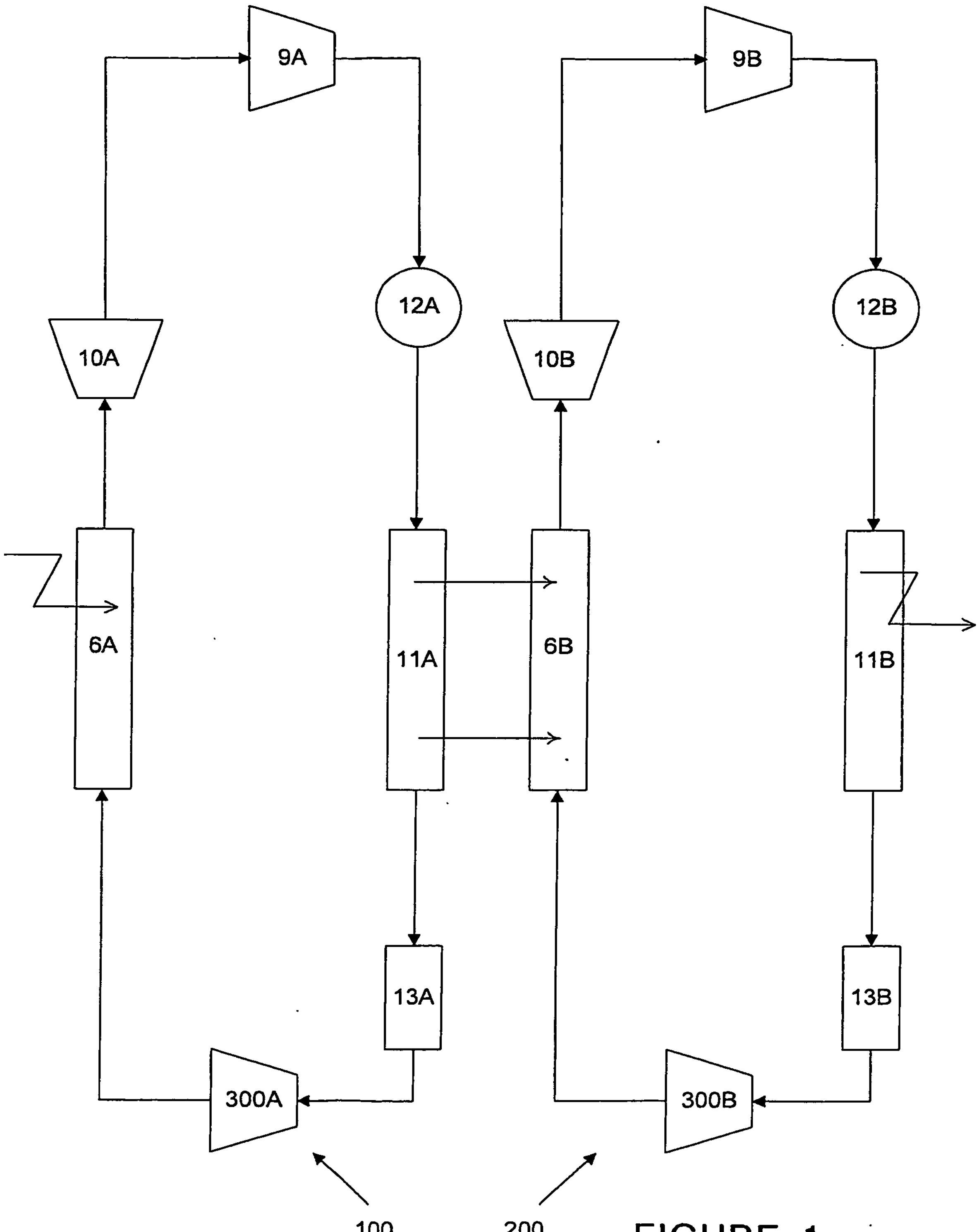

FIGURE 1

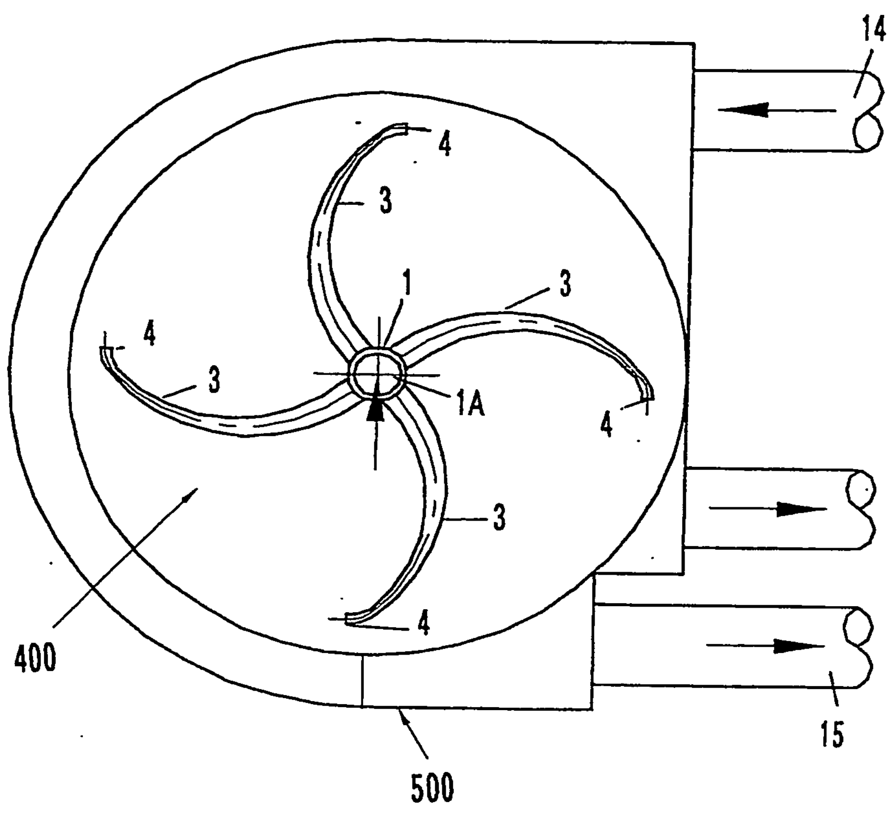

FIGURE 2

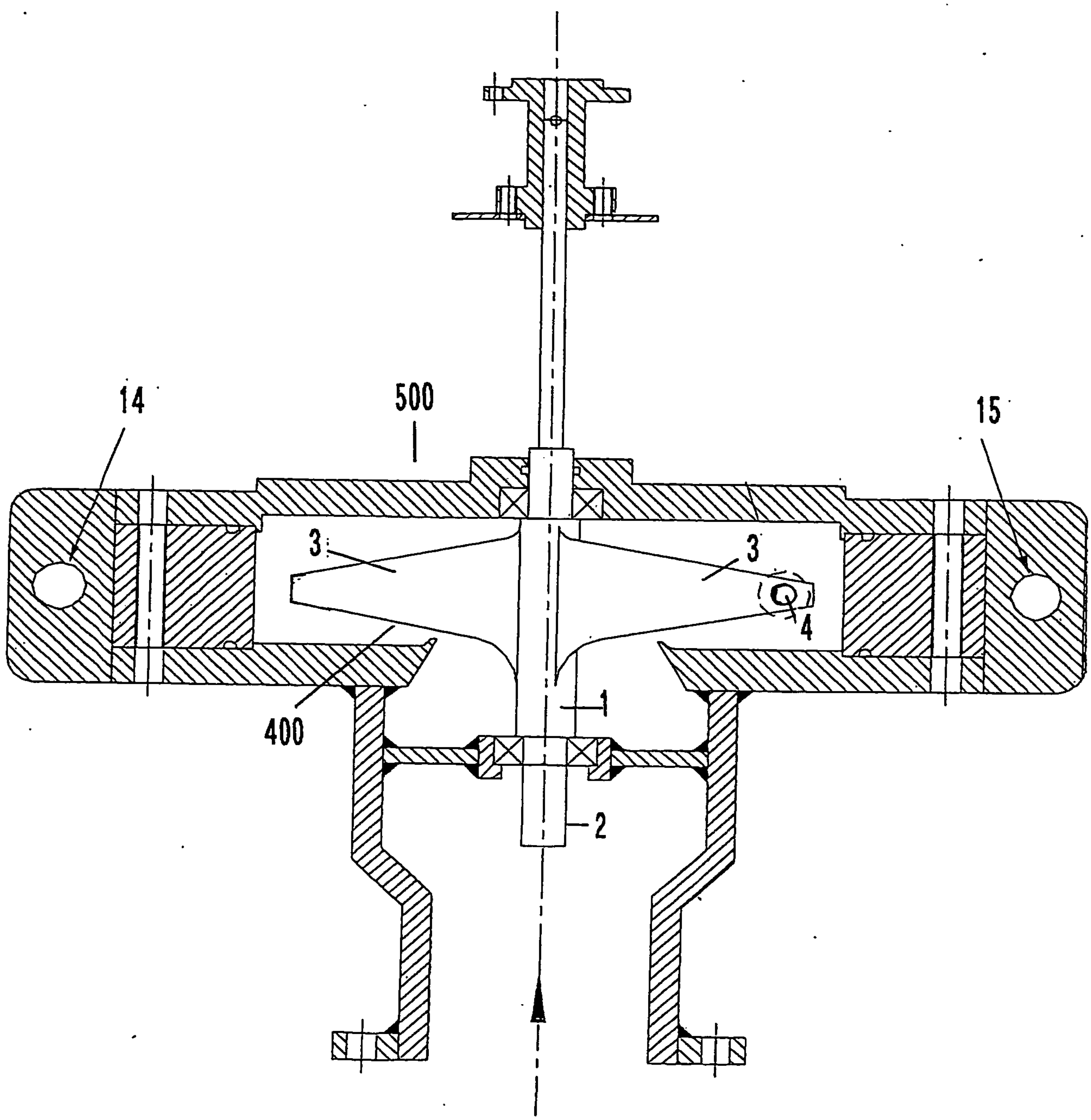

FIGURE 3

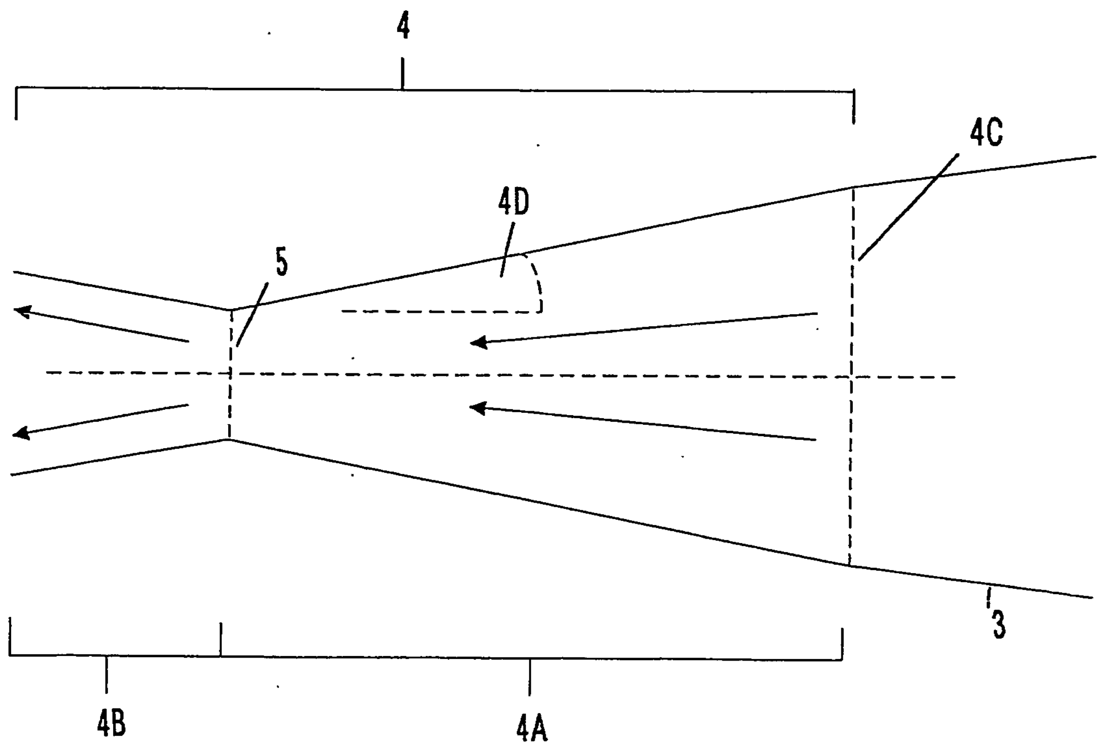

FIGURE 4

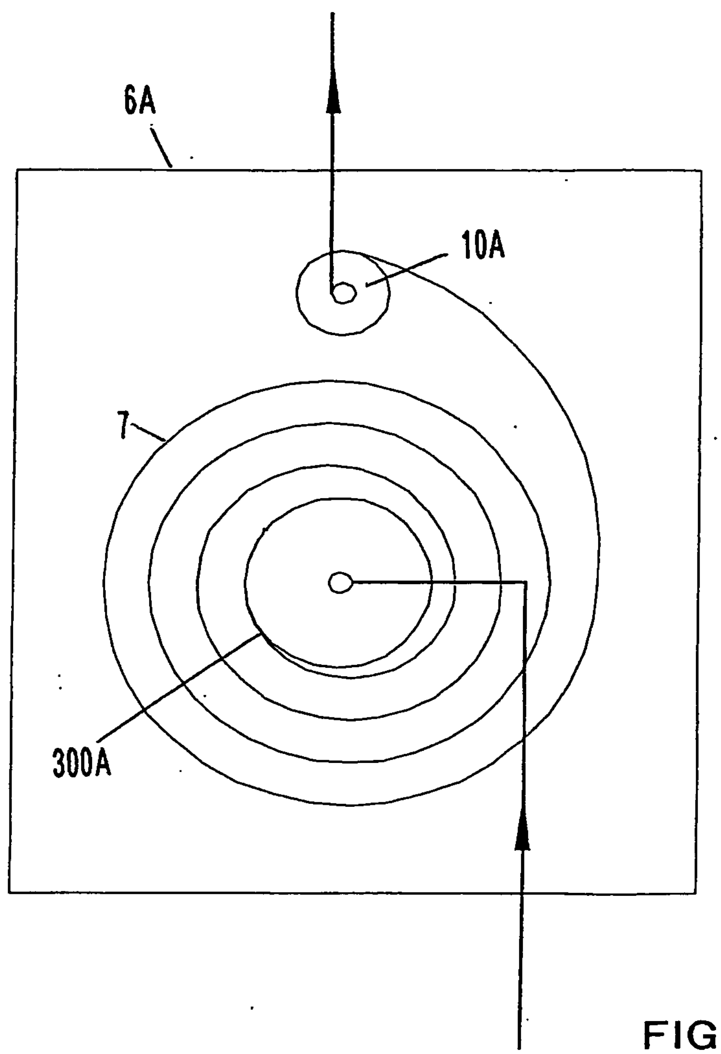

FIGURE 5